INVESTIGATION OF ULTRASONIC WELDING OF REFRACTORY METALS AND ALLOYS

March 1963

Prepared under Navy Bureau of Naval Weapons
Contract No. NOw 63-0125-c

Bimonthly Progress Report No. 3

16 December 1962 through 15 February 1963

AEROPROJECTS INCORPORATED
WEST CHESTER, PENNSYLVANIA

UNCLASSIFIED

INVESTIGATION OF ULTRASONIC WELDING OF REFRACTORY METALS AND ALLOYS

March 1963

Prepared under Navy Bureau of Naval Weapons
Contract No. NOw 63-0125-c

Bimonthly Progress Report No. 3
16 December 1962 through 15 February 1963

AEROPROJECTS INCORPORATED
WEST CHESTER, PENNSYLVANIA

UNCLASSIFIED

INVESTIGATION OF ULTRASONIC WELDING OF REFRACTORY METALS AND ALLOYS

ABSTRACT

Both power and clamping force associated with ultrasonic welding have been successfully programmed. By means of a servo-controlled hydraulic valve in the clamping force system, the previously reported inadequate force response times have been improved and are now adequate for carrying out the projected welding of refractory metals with this improved technique. Tentative specifications for refractory metals of reasonably satisfactory quality have been established.

TABLE OF CONTENTS

INVESTIGATION OF ULTRASONIC WELDING OF REFRACTORY METALS AND ALLOYS

LIST OF FIGURES

INVESTIGATION OF ULTRASONIC WELDING OF REFRACTORY METALS AND ALLOYS

The ultrasonic welding cycle involves an induction period wherein the sonotrode tip slips during the establishment of coupling, and an interval wherein tip amplitude may decrease as the weld is generated. The slip interval produces heat that is probably unnecessary, and the interval of amplitude decline seems to be associated with high cyclic stresses in the weldment. The programming of power and clamping force will operate to reduce power, to improve control, and to extend the utility of the process. Thus, the work here discussed is concerned with power-force programming and with the specific objective of joining refractory metals.

The division of the work and development effort is presented in the program control chart included in Progress Report No. 2, Figure 3.

A summary of the work executed during this period follows:

Power-Force Programming Equipment

A. Power Programming

Circuitry has been designed and assembled to control the application of ultrasonic welding power on the basis of any program set out on the power control panel (Figures 1 and 3A).

Initial measurements of the power control signal programmed in progressive 10 percent increments of the pre-set maximum signal level show that the power control signal does not respond with uniform increments (Figures 3-A and 3 B-1). This is due to the electronic circuitry constants associated with the oscillator drive and its coupling circuits into the power amplifiers. Such deviation from linearity will be corrected.

B. Force Programming

It was previously shown (Figure 1-B, Progress Report No. 2) that various devices controlling the applied clamping force did not have sufficiently fast response to meet the requirements that have appeared necessary. A high-response servo valve and associated servo amplifier were adapted for use on the laboratory welder shown in Figure 1.

Figure 2 summarizes the results obtained progressively with the force system to date. Figure 2-A reproduces an actual strip-chart oscillogram of the clamping force when a single step signal is applied to the system incorporating the shear valve (as reported in Progress Report No. 2).

Figure 2-B shows the actual response when a step signal is applied to the system incorporating the new servo valve and amplifier. Figure 2-C reproduces several previous response plots (curves B, C, and D which were described in Figure 1-B, Progress Report No. 2) and the properly scaled response curve of "B". Thus, the servo valve and associated amplifier permit realization of the force response requirements initially deemed desirable.

Scouting investigations were carried out with the complete power-force program controlled welder in joining 0.040-inch thick and 0.050-inch thick 2024-T3 bare aluminum and using 0.015-inch Mo-0.5Ti. No quantitative weld data have yet been obtained, but it appears that the power-force program control system is functioning as intended.

Weldment Materials

The materials selected for this investigation include Inconel-X and AlSI 304 stainless steel for the preliminary evaluation of power-force programming, plus Mo-0.5Ti, one columbium-base alloy and tungsten for later work. Inconel-X has been secured in 0.025 and 0.031-inch thickness, and the AlSI 304 stainless steel in 0.030, 0.040, and 0.050 inch thickness. It has not yet been possible to secure any of the three refractories with the desired quality. Such metals acquired previously have exhibited serious surface and subsurface contamination, brittleness, and recrystallization.

Review of information, and discussion with manufacturers and users of refractory metals* produced sufficient information on Mo-0.5Ti and tungsten to establish procurement specifications for these two. However, the recrystallization encountered in D-31 columbium alloy, and the lack of rigorous information concerning it, indicated that this alloy can probably not be procured currently in the desired consistent quality. D-31 columbium alloy should probably be dropped from the investigation, and one of the columbium-base refractory alloys listed below substituted. Available technical information, consultation with material manufacturers, and careful consideration of the requirements for consistent high-quality metal, indicate that one of these should be satisfactory.

Alloy	Manufacturer
B-33 B-66	Westinghouse
C-103	Wah Chang
FS-82	Fansteel

Procurement of Mo-0.5Ti, tungsten, B-33, and C-103 is in process, and efforts to procure small quantities of B-66 and FS-82 are being made.

* A summary of this research effort, including communication with various manufacturers, will be included in a later report.

Future Work

1. The completely assembled power-force program system will be utilized in exploratory welding of materials on which much data is available: aluminum alloys, 304 stainless steel, and Inconel-X with the view to determining the effects on strength, and weld-quality variation.

2. Continued effort to obtain quality materials.

REFERENCES

1. Aeroprojects Incorporated, "Ultrasonic Welding of Refractory Metals", under Navy Contract No. NOw-61-0410-c.

2. Jones, J. B., H. L. McKaig, and J. G. Thomas, "Investigation of Ultrasonic Welding of All-Beta Titanium Alloy." Research Report 61-77, Navy Contract NOw 60-0643, September 1961.

3. Aeroprojects Incorporated, "Development of Ultrasonic Welding Equipment for Refractory Metals - Phase II", under Air Force Contract No. AF 33(600)-43026.

4. Jones, J. B., N. Maropis, J. G. Thomas, and D. Bancroft, "Fundamentals of Ultrasonic Welding, Phase I." Research Report 59-105, Navy Contract NOas 58-108-c, May 1959.

5. Jones, J. B., N. Maropis, J. G. Thomas, and D. Bancroft, "Fundamentals of Ultrasonic Welding, Phase II." Research Report 60-91, Navy Contract NOa(s) 59-6070-c, December 1960.

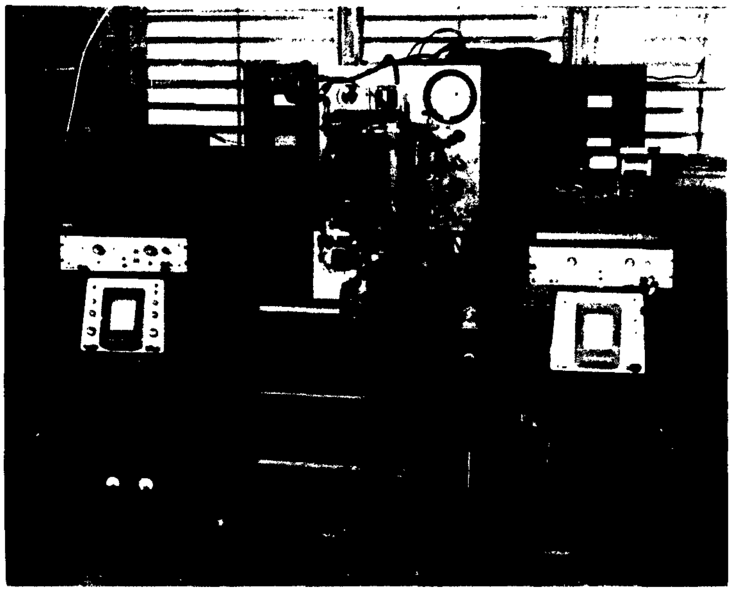
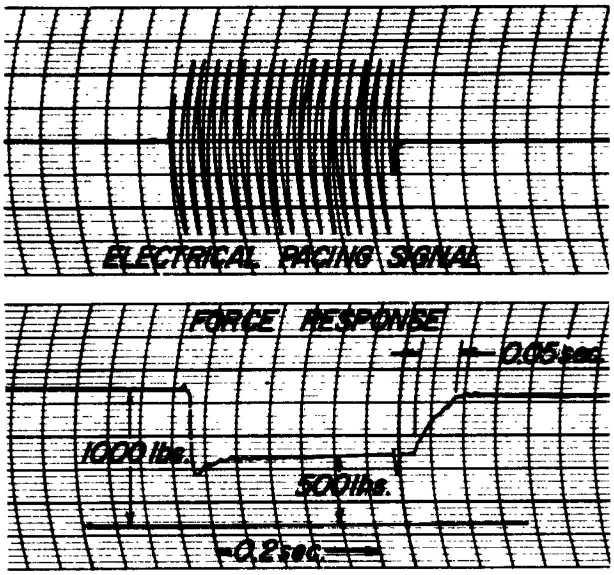
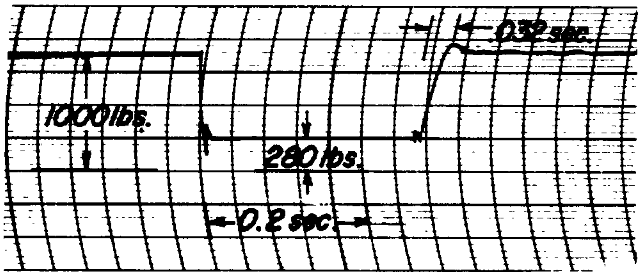


Figure 1

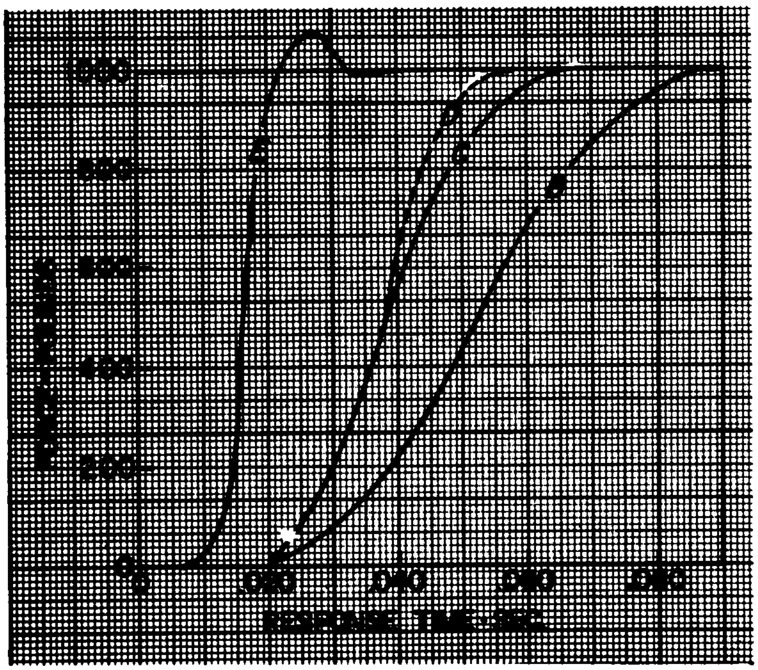
4-KILOWATT ULTRASONIC WELDER WITH EXPERIMENTAL POWER-FORCE CONTROLS AND ASSOCIATED RECORDING INSTRUMENTATION



A RESPONSE CURVE TO SINGLE-STEP CONTROL AND 60-CYCLE PACING SIGNAL (SHEAR-SEAL VALVE)



B RESPONSE CURVE TO SINGLE-STEP CONTROL (SERVO VALVE)

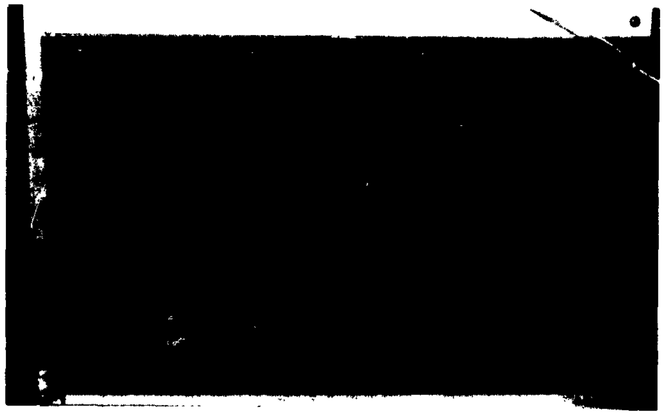


C FORCE RESPONSE CURVES

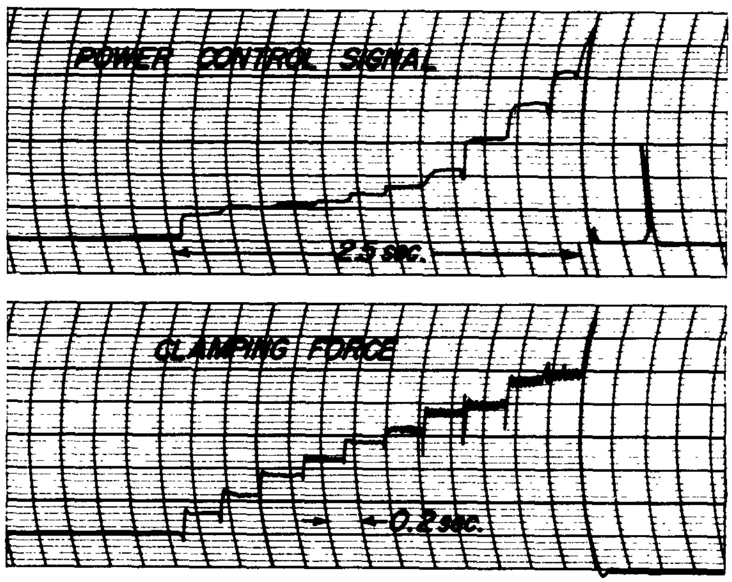
- B - Solenoid-Controlled High-Response Shear-Seal Valve
- C - Addition of Low Pressure Cut-off in Control Line
- D - Estimated Response of "C" Condition with Addition of Pressure Accumulator
- E - Response with Servo-Valve By-Pass Control

Figure 2

RESPONSE CURVES FOR SHEAR-VALVE AND SERVO-VALVE FORCE CONTROL



A POWER-FORCE PROGRAM CONTROL PANEL SET FOR PROGRESSIVE INCREASES OF EACH PARAMETER



1

2

B RECORDED POWER CONTROL SIGNAL AND RECORDED CLAMPING FORCE FOR SETTINGS SHOWN IN "A" ABOVE

Figure 3

DISTRIBUTION COPIES

Number of Copies	
12 and 1 repro	Chief, Bureau of Naval Weapons Washington 25, D. C. Attention: DLI-31 RRMA-24 (6) PID-2 (1) NPR-531 (1) SP-27 (1) RMMP-23 (1) DLI-31 (2)
10	Armed Services Tech. Info. Agency Arlington Hall Station Arlington 12, Virginia Attn: Document Service Center (TICSCP)
2	Office of Technical Service Department of Commerce Washington 25, D. C.
1	Chief, Bureau of Ships Department of the Navy Attn: Code 634B Washington 25, D. C.
1	Commanding Officer Naval Ordnance Laboratory White Oak, Silver Spring Maryland Attn: Technical Library
1	Chief, Naval Research Laboratory Department of the Navy Washington 25, D. C. Attn: Mr. W. Pellini, Supt. Metallurgy Dept.
1	Chief, Office of Naval Research Department of the Navy Washington 25, D. C. Attn: Metallurgy Section
1	Commanding Officer Naval Air Engineering Center Philadelphia 12, Pennsylvania Attn: Metallurgy Division, AML

Number of Copies	
1	Commanding Officer Naval Ordnance Test Station China Lake, California Attn: Code 55
1	U. S. Army Research Office 3045 Columbia Pike Arlington 4, Virginia Attn: Mr. A. L. Tarr
1	Headquarters, Army Material Command Washington 25, D. C. Attn: AMCRD-RS-CM
1	Commanding Officer Watertown Arsenal Watertown, Massachusetts Attn: Mr. N. L. Reed, Ordnance Materials Research Office
1	Commanding General Frankford Arsenal Philadelphia 37, Pennsylvania Attn: Mr. J. J. Power, Jr.(ORDBA-LMJ)
1	Army Ballistic Missile Agency Redstone Arsenal Huntsville, Alabama Attn: Chief, Materials Branch Development Operations Division
1	Commanding Officer Watertown Arsenal Laboratories Watertown 72, Massachusetts Attn: Mr. S. V. Arnold, Associate Director
1	Commanding Officer Army Rocket and Missile Agency Redstone Arsenal, Alabama Attn: Technical Library (ORDXR-OTC)

DISTRIBUTION LIST (Continued)

1 Commanding Officer
Army Chemical Corps Command
Munitions Division
Army Chemical Center, Maryland
Attn: Mr. Joseph Trost

1 Commanding Officer
Engineering Res. & Dev. Lab.
Department of the Army
Fort Belvoir, Virginia
Attn: Metallurgical Dept.

1 Commander
Aeronautical Systems Division
Attn: Metals & Ceramics Laboratory (ASRCM)
Wright-Patterson Air Force Base, Ohio

1 Commander
Aeronautical Systems Division
Attn: Applications Lab. (ASRCE)
Wright-Patterson Air Force Base, Ohio

2 Commander
Aeronautical Systems Division
Attn: Manufacturing Technology Laboratory (ASRCT)

3 Director
National Aeronautics and Space Admin.
1520 H Street, N. W.
Washington 25, D. C.

1 The Arnold Engineering Company
P. O. Box C
Marengo, Illinois
Attn: Mr. Benjamin Falk

1 Atomic Energy Commission
Germantown, Maryland
Attn: Mr. J. Simmons, Div. of Reactor Development

2 Brookhaven National Laboratory
Information and Publication Service
Uptown, New York
Attn: Miss Mary Weismann, Document Section

1 U. S. Atomic Energy Commission
Attn: Technical Information Service
Oak Ridge, Tennessee

1 National Academy of Sciences
2101 Constitution Avenue, N. W.
Washington 25, D. C.
Attn: Dr. J. Lane, Metallurgist
Materials Advisory Board

3 Aerospace Industries Association
Technical Services Division
Shoreham Building
Washington 5, D. C.

1 Welding Research Council of the
Engineering Foundation
345 East 47th Street
New York 17, New York

2 Battelle Memorial Institute
Defense Metals Information Center
Attn: Mr. C. S. DuMont
505 King Avenue
Columbus 1, Ohio

1 Battelle Memorial Institute
505 King Avenue
Columbus 1, Ohio
Attn: Mr. M. J. Rieppel
Chief, Metals Joining Division

1 Armour Research Foundation
Illinois Institute of Technology
Metals Research Dept.
3350 S. Federal Street
Chicago 16, Illinois
Attn: Dr. W. Rostoker

1 Renssalaer Polytechnic Institute
Department of Metallurgical Eng.
110 Eight Street
Troy, New York
Attn: Dr. Earnest Nippes

DISTRIBUTION LIST (Continued)

1 Ohio State University
Department of Welding Engineering
Columbus, Ohio
Attn: Prof. R. B. McCauley

1 Massachusetts Institute of Technology
Metallurgy Department
Cambridge 39, Massachusetts
Attn: Dr. Clyde Adams

1 New York University
College of Engineering
New York 53, New York
Attn: Dr. C. C. Goetzel, Res. Div.

1 University of California
Los Alamos Scientific Laboratory
Los Alamos, New Mexico
Attn: Mr. J. R. Taub, Group Leader

1 Pratt & Whitney Division
United Aircraft Corporation
Connecticut Aircraft Nuclear
Engines Laboratory
Middletown, Connecticut
Attn: Mr. L. M. Raring, Chief
Metallurgist

1 The Martin Company
Attn: Chief, Manufacturing Res. &
Development Laboratory
Denver 1, Colorado

1 Crucible Steel Company
Titanium Division
Midland, Pennsylvania
Attn: Dr. Walter L. Finley

2 Mallory Sharon Titanium Corporation
Niles, Ohio
Attn: Dr. L. S. McCoy
Dr. L. S. Busch

1 North American Aviation, Inc.
Los Angeles Division
International Airport
Los Angeles, California
Attn: Mr. H. D. Mason,
Engineering Section

1 North American Aviation, Inc.
Columbus Division
4310 N. 5th Avenue
Columbus, Ohio
Attn: Mr. Paul Maynard, Chief of
Materials

1 Westinghouse Electric Corporation
Research Laboratories
Beaulah Road, Churchill Boro
Pittsburgh 35, Pennsylvania
Attn: Chief, Metals Joining Section

1 Gulton Industries, Inc.
212 Durham Avenue
Metuchen, New Jersey
Attn: Director, Research & Dev.

1 Circo Ultrasonic Corporation
Attn: Mr. B. Carlin, Vice-President
51 Terminal Avenue
Clark, New Jersey

1 The Budd Company
Defense Division
2450 Hunting Park Avenue
Philadelphia 32, Pennsylvania
Attn: Chief, Metallurgy Dept.

1 Sciaky Brothers, Inc.
4915 W. 67th Street
Chicago 38, Illinois
Attn: Mr. W. J. Farrell, Chief
Applications Engineer

1 Climax Molybdenum Company
1410 Woodrow Wilson Avenue
Detroit 3, Michigan
Attn: Mr. A. J. Herzig

DISTRIBUTION LIST (Continued)

1 Universal-Cyclops Steel Corporation
Refractomet Division
Bridgeville, Pennsylvania
Attn: Mr. C. Mueller, Mgr.

1 General Electric Company
Applied Research Operations
Flight Propulsion Laboratory Dept.
Cincinnati 15, Ohio
Attn: Mr. Louis P. Jahnke, Mgr.
Metallurgical Engineering

1 General Electric Company
Missile and Ordnance Systems Dept.
3750 D Street
Philadelphia 24, Pennsylvania
Attn: Aerosciences Laboratory

1 Boeing Airplane Company
P. O. Box 3707
Seattle 34, Washington
Attn: Mr. John T. Stacey, Senior
Group Engineer, Aerospace Div.

2 Republic Aviation Corporation
Farmingdale, Long Island, New York
Attn: Dr. S. Korman, Chief,
Materials Dev., R.A.C
Attn: Mr. T. F. Imholtz,
Manufacturing Research

1 Lockheed Aircraft Corporation
Burbank, California
Attn: Mr. E. Green, Mgr.,
Production Engineering Dept.

1 Lockheed Aircraft Corporation
Missiles and Space Division
Sunnyvale, California
Attn: Mr. Alfred Peterson, Mgr.,
Production Eng. Dept. 83-31

1 Aerojet General Corporation
Solid Rocket Plant
Sacramento, California
Attn: Mr. Alan V. Levy
Head, Materials R&D Dept.(4610)

1 Lockheed Aircraft Corporation
Missile and Space Division
3251 Hanover Street
Palo Alto, California
Attn: Mr. R. A. Perkins
Metallurgist & Ceramic Res.

1 General Telephone and Electronics
Laboratories, Inc.
P. O. Box 59
Bayside, New York
Attn: Dr. L. L. Seigle, Mgr.
Metallurgical Lab.

1 National Aeronautics & Space Admin.
Lewis Research Center
21000 Brookpark Road
Cleveland 35, Ohio
Attn: Mr. Mervin Ault, Asst. Chief
Materials & Structures Div.

1 Boeing Airplane Company
Seattle 24, Washington
Attn: Dr. Edward Czarnecki, Mgr.
Materials Mechanics & Structures
Branch
Systems Management Office

1 Fansteel Metallurgical Corporation
North Chicago, Illinois
Attn: Mr. Alan F. Busto, Technical
Administrator

1 Massachusetts Institute of Technology
Cambridge 39, Massachusetts
Attn: Dr. Walter A. Backofen
Associate Prof. of Metallurgy

1 Grumman Aircraft Engineering Corp.
Bethpage, Long Island, New York
Attn: Mr. Earl Morris, Materials
Engineering

DISTRIBUTION LIST (Concluded)

1 Commanding Officer
Picatinny Arsenal
Dover, New Jersey
Attn: Mr. George Van Syckle
Building 65, TAWC

1 Massachusetts Institute of Technology
Department of Aeronautics and Astronautics
Instrumentation Laboratory
Cambridge 39, Massachusetts
Attn: Miss Betty Robinson
Ass't. Librarian

1 Delco Remy Division
General Motors Corporation
Anderson, Indiana
Attn: Mr. J. R. West, Piress Dept.

1 Inspector of Naval Material
10 North 8th Street
Reading, Pennsylvania

1 Branson Instruments, Incorporated
37 Brown House Road
Stamford, Connecticut

1 P. R. Mallory and Company, Inc.
Indianapolis 6, Indiana
Attn: Mr. A. S. Doty, Director,
Technical Services Laboratories